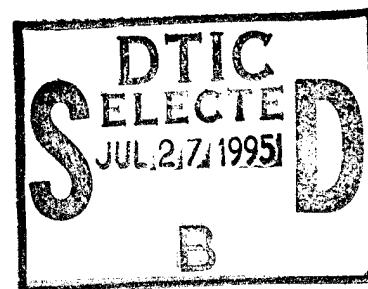




**U.S. Army Aviation Epidemiology Data Register:
Incidence of Color Vision Deficiency
Among U.S. Army Aviators**

By

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and

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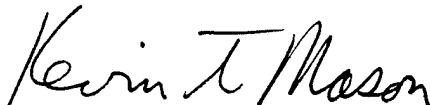
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Since aviator training applicants are disqualified routinely from training due to color vision deficiency, there should be no aviators with color vision deficiency. However, this paper details incidents of exception to policy for known color vision deficiency, acquired color vision deficiency, and aviation medicine clinic screening program failures due to poor methods or deception by applicants and conspirators. The in-flight evaluation of aviators discovered to have color vision deficiency is described.				
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19. Abstract (Continued):

The incidence of color vision deficiency was determined by a review of records in the U.S. Army Aviation Epidemiology Data Register (AEDR), to include archived aeromedical board documents, for the period of calendar years 1982 to 1992. Color vision deficiency among Army aviators is rare with an incidence of about one new case per 10,000 aviator-years per year. Two of twenty-nine were granted exceptions to policy to complete flight training with color vision deficiency. The others (27 of 29) were granted administrative waivers to continue flying duties with their condition. Only half of the color vision deficient aviators underwent ophthalmology or optometry consultation. Only 17 percent (5 of 29) underwent an attempt to discover the axis of color vision deficiency. Only 59 percent (17 of 29) underwent in-flight evaluations, despite the longstanding aeromedical policy requirement for all aviators with color vision deficiency to undergo in-flight evaluations.

The authors make multiple recommendations to visual scientists and to aeromedical policy and standards decision makers.

Table of contents

	Page
List of tables	1
Military relevance	3
Background	3
Screening for color vision deficiency	3
Screening aviation training applicants	3
Exceptions to policy	3
Acquired versus congenital color vision deficiency	4
Screening program failure	5
Screening trained aviators by inflight evaluation	6
Method	6
Results	6
Discussion	7
Conclusions and summary	9
References	10
Other relevant references not cited	12

List of tables

Table

1. A comparison of acquired and congenital color vision deficiency
2. Incidence of color vision deficiency waivers per 1,000 aviator-years by calendar year
3. Findings among the color vision deficient subjects

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Military relevance

Chief, Visual Sciences Branch, U.S. Army Aeromedical Research Laboratory, requested an epidemiologic survey of color vision deficiency among U.S. Army aviators. Color vision requirements for Army aviators are more complex as new cockpit systems rely on multicolored displays. The analysis was based on historical data contained in the U.S. Army Aviation Epidemiology Data Register (AEDR).

Background

Screening for color vision deficiency

Screening applicants to flight training

Aviator training applicants are screened for color vision deficiency during the initial flying duty medical examination (FDME). Those with 5 or more errors on the 14-plate pseudoisochromatic plate series (PIP), and/or those with any errors on the 9 test pairs of the Farnsworth lantern (FALANT) are disqualified for entry into training (Department of the Army, 1995; Mason, 1995). An unknown number of potential applicants with color vision deficiency are not reported to the central FDME review process. Advisors may tell them to not bother applying to flight training. A flight surgeon may do an informal screening and advise the applicant to not pursue the application process further. So the exact prevalence of color vision deficiency among applicants is unknown.

Failure to meet color vision screening standards is considered a major medical disqualification for Army aviator training. It is presumed that all Army aviators with color vision deficiency either have an exception to policy to enter flight training with a known color vision deficiency, have acquired color vision deficiency, or were screening program failures due to poor screening methods by the FDME examiners or deception by the applicant or other conspirators.

Exceptions to policy

Exceptions to policy (ETP) are given to exceptional applicants who have minor, stable medical disqualifications for entry into flight training. For example, hemoglobinopathy and anemia are disqualifying. But one hemoglobinopathy, beta thalassemia minor, is unlikely to progress, decrease operational performance, or cause incapacitation. A cadet, in the upper tenth percentile of achievement in academic, physical, and military training, may have beta thalassemia minor with mild anemia. An ETP might be considered for this exceptional individual and circumstance. In the case of congenital color vision deficiency, the condition is stable, but presents with many degrees of deficiency that may be operationally significant. Historically, ETPs have been granted rarely for color vision deficiency (3 among an estimated 70,000 applicants from 1982 to 1994, unpublished AEDR data set of the first author). The basis of this decision includes color vision deficient

individuals have a greater risk for mishap at the controls of ground vehicles (Verriest et al., 1980) and aircraft (Dille and Booze, 1979), have reduced visual acuity in certain lighting conditions compared to normals (Adams and Tague, 1985), and have difficulty reacting to, properly identifying, and/or seeing warning colors in the operational environment (Farnsworth, 1946; Sloan and Habel, 1955a; Sloan and Habel, 1955b; Heath and Schmidt, 1959; Nathan, Henry, and Cole, 1964; Watkins, 1971; Steen, Collins, and Lewis, 1973; Vingrys and Cole, 1988). The operational color vision disability is worse in protanopic aircrew compared to deutanopic aircrew (Ruff and Schmidt, 1940; Heath and Schmidt, 1959; Kuyk et al., 1987).

Acquired versus congenital color vision deficiency

Table 1 shows a comparison of acquired and congenital color vision deficiency (Hart, 1992). Aviators with acquired deficiency require a thorough evaluation to rule out serious underlying conditions. Unfortunately, acquired deficiency is more difficult to detect by PIP and FALANT screening tests since these tests were designed primarily to detect binocular congenital deficiency. Fortunately, aviators with acquired deficiencies are likely to present for evaluation due to worrisome symptoms of changing color vision perception.

Table 1.
A comparison of acquired and congenital color vision deficiency.

Category	Color vision defect	
	Acquired	Congenital
Prevalence in population	<1.0 percent	6-8 percent of men and 0.5 percent of women
Patient complaint	Realize they have lost color discrimination capability, very bothersome	Do not notice lost color perception, unless pointed out to them or they can not perform a color dependent task
Scope of defect	May be monocular and/or affect only a portion of a visual field	Binocular and affects entire visual field
Associated symptoms	Noticeable decrease in visual acuity and/or dark adaptation	Do not always notice decrease in visual acuity. Dark adaptation is normal.
Underlying disorder	Retinal, optic nerve, or visual cortex disease; medication use	Abnormality of retinal photosensitive pigment composition
Axis of defect	Blue-yellow axes affected in addition to red-green axes	Affects predominately red-green axes

The first author evaluated an air traffic controller who complained of loss of color discrimination at night. An air traffic control tower evaluation revealed the controller no longer could identify the aircraft marker lights which gave visual cues as to the type of aircraft and direction of travel. Color vision tests and ocular examination were normal. Evaluation led to a trial of glasses to correct night myopia, which corrected the color vision defect. In another case, an aviator presented with a complaint of a reduction in color vision and visual acuity in one eye. Color vision testing was abnormal in that eye. Further evaluation led to the discovery of glaucoma.

Screening program failure

Screening programs for aircrew members may fail for multiple reasons. Most commonly, screening program failures are due to poor methods, inaccurate recording of results, and fraud. Screening program failures examples are from the following personal experiences of the first author.

A routine inspection of an aviation medicine clinic revealed that the answer to the PIP presentation plate was written in pencil by the medic on the back of the preceding plate as a reminder to the medic of the correct response for the presentation plate. Color vision deficient aviation training applicants can quickly determine the significance of the penciled number and falsely pass the PIP test in this clinic. Other investigators reported this same finding in other clinics.

A flight training applicant knew he was color vision deficient. He consulted his family optometrist who fit one eye with a red-colored, X-Chrom contact lens to enhance the applicant's chance of passing the screening PIP plates. The lens was discovered when the first author performed a slit lamp examination of the applicant during the vision screening session. Use of this lens significantly improves PIP, Dvorine color vision plate, and Farnsworth-Munsell 100-hue color vision test scores; but not FALANT scores (LaBissoniere, 1974; Ditmars and Keener, 1976; Welsh, Vaughan, and Rasmussen, 1978).

An investigation of a series of failed color vision screening tests on the applicant's second FDME, but not on the first FDME, led to the discovery that a majority of these applicants had their first FDME performed at one aviation medicine clinic. The flight surgeon in this clinic admitted that he had a habit of overlooking color vision deficiencies among applicants. If he thought the color vision deficient applicant would otherwise be a "true air warrior," he would transcribe false results on the FDME. The applicants compounded the ethical dilemma since they knew they were color vision deficient, but accepted the false results on the first FDME. During the investigation, one interviewed applicant stated, "Cheating is an acceptable means to achieve your goals. The honor code is violated only if you get caught."

An applicant correctly identified all 14 PIP plates. However, the first author was suspicious of color vision deficiency during the physical examination due to other testing cues. The PIP plates were shuffled, and the color vision screening was repeated. The applicant then missed 12 of 14 PIP plates and was medically disqualified. A medic in the clinic admitted he coached the color vision

deficient applicant, his friend, on the correct answers to the PIP series before the applicant arrived for his FDME.

Screening trained aviators by inflight evaluation

Several publications discussed the concept of screening inflight evaluation for Army aviators with color vision deficiency discovered after flight training. Army aviators failing PIP and/or FALANT complete inflight evaluations to demonstrate their operational color vision proficiency. The inflight evaluation includes routinely presentations with the control tower Aldis light gun using red, green, and white challenges; and the smoke bomb test using various signal colors, to include white, red, yellow, green, and violet. These tests require objective identification of randomly presented colors with binomial scoring. Some flight surgeons conducting inflight evaluations include testing of color discrimination on map reading, tactical glide slopes, runway lighting, and aircraft beacon lighting. These latter tests are more subjective than the light gun and smoke bomb tests with correct responses learned by flying experiences. The policy is that aviators with color vision deficiency who do not pass these inflight, operational tests will not be given a waiver to continue Army aviation service (Appleton, 1972; Ward et al., 1976; Department of the Army, 1989).

Method

The AEDR flight physical history database, and waiver and suspension files were searched for codes related to color vision deficiencies for the period of calendar years 1982 to 1992. A case was defined as an Army aviator who was discovered to have color vision deficiency after entrance into the aviator training program at Fort Rucker. The aeromedical board documents and AEDR flight physical data were reviewed to confirm the presence of color vision deficiency. The following data elements were extracted from records: patient's name, Social Security number, age at diagnosis, calendar year of diagnosis, aeromedical board disposition for continued flying duties, component of service, and rank. The database contained also the results of pseudoisochromatic plates test (PIP), Farnsworth lantern test (FALANT), control tower light gun test, colored smoke bomb test, Munsell's D-15 and D-100 hue tests, and optometric or ophthalmologic consultations. For calculation of the incidence rates, an estimate of the aviator-years of exposure per calendar year was obtained from AEDR reference tables (Mason and Shannon, 1994).

Results

Table 2 shows the number of new cases of Army aviators with color vision deficiency for calendar years 1982 to 1992, and the incidence of color vision deficiency cases per 1,000 aviator-years by calendar year. The incidence was not calculated for calendar years 1982 to 1985 since there is no known estimate of the aviator-years for these years. About 1 new Army aviator per 10,000 Army aviators per year had color vision deficiency after entrance into flight training. Of the 29

cases, 27 were aviators granted waivers for flying duties, and 2 were exceptions to policy granted to Army aviator students discovered to have color vision deficiency after arrival at Fort Rucker, Alabama, for aviator training.

Table 2.

Incidence of color vision deficiency waivers per 1,000 aviator-years by calendar year.

Color vision deficiency waivers granted	Calendar year										
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Number of new cases	2	2	2	2	8	2	2	1	2	4	2
Incidence	-	-	-	-	0.42	0.09	0.09	0.05	0.09	0.18	0.10

Table 3 shows the findings among the color vision deficient subjects in the study. The age of the aviator at discovery of the color vision deficiency ranged from 23 to 59. All of the subjects failed the PIP screening test. Of the 72 percent (21 of 29) who took the FALANT screening test, all failed the FALANT. The color smoke bomb and tower light gun tests were administered to 55 percent (16 of 29), and all passed. One aviator was given the tower light gun test only, and failed, but was still granted a waiver. Only 55 (16 of 29) percent had ophthalmology or optometry consultation. Only 17 percent (5 of 29) had a basic attempt to discover the axis of their color vision deficiency by use of the D-15 hue test. Four of the five had deutanopia, the other had protanopia.

Discussion

As expected, since color vision deficient applicants are denied routinely entry into Army aviator flight training, the incidence of color vision deficiency among Army aviators is rare, on the order of 1 new case per 10,000 aviator-years per year. Thus, we presume most of these cases should be acquired color vision deficiency, which is caused usually by a serious underlying visual system disorders or use of medications that can cause retinopathy. Therefore, it is disconcerting to find that only half of the aviators underwent an evaluation by an eye health care professional.

Given that all but one of the aviators with color vision deficiency passed their operational color vision tests (light gun and smoke bomb), we can presume that most of the aviators have anomalous (partial loss) of color vision in their axis of deficiency. Deutanomalous observers are less prone to colored aviation signal errors than protanomalous observers (Heath and Schmidt, 1959; Kuyk et al., 1987). Fortunately, of our aviators who underwent diagnostic testing (5 of 29), most (4 of 5) had mild to moderate deutanomalous color vision deficiency, rather than protanomalous color vision deficiency. It would be prudent to conduct diagnostic testing to determine the degree and axis of color vision deficiency in all aviators who fail color vision screening tests.

Table 3.
Findings among the color vision deficient subjects.

Subject	Year of waiver	Age that year	Years of flying after service	Component	Grade of service	PIP	Falant	Color smoke	Tower lights	D15 test	Ophthalmology/ophtalmometry consult?
1	1982	28	12	Active duty	Warrant	Fail	-	-	-	-	No
2	1982	30	12	Active duty	Warrant	Fail	Fail	Pass	Pass	Deuteranopia	Yes
3	1983	31	11	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	No
4	1983	47	11	Civilian	Civilian	Fail	-	-	-	-	No
5	1984	28	10	Active duty	Commissioned	Fail	-	-	-	-	No
6	1984	31	10	Active duty	Commissioned	Fail	Fail	-	-	Deuteranopia	Yes
7	1985	27	8	Active duty	Warrant	Fail	-	-	-	-	No
8	1985	34	2	Active duty	Warrant	Fail	-	-	-	-	No
9	1986	23	8	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
10	1986	27	6	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
11	1986	28	8	USAR	Warrant	Fail	Fail	-	-	-	Yes
12	1986	33	2	ARNG	Warrant	Fail	Fail	-	-	-	No
13	1986	34	5	Active duty	Warrant	Fail	-	-	-	-	No
14	1986	36	8	ARNG	Warrant	Fail	Fail	Pass	Pass	-	Yes
15	1986	36	7	ARNG	Warrant	Fail	-	-	-	-	No
16	1986	39	3	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	No
17	1987	24	7	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
18	1987	25	1	Active duty	Warrant	Fail	Fail	Pass	Pass	Deuteranopia	Yes
19	1988	25	6	ARNG	Warrant	Fail	Fail	Pass	Pass	-	Yes
20	1988	43	3	Active duty	Warrant	Fail	Fail	Pass	Pass	-	Yes
21	1989	31	5	Active duty	Warrant	Fail	Fail	Pass	Pass	-	Yes
22	1990	35	4	Active duty	Warrant	Fail	Fail	Pass	Pass	-	No
23	1990	59	1	ARNG	Warrant	Fail	Fail	-	-	Deuteranopia	Yes
24	1991	33	1	Active duty	Commissioned	Fail	-	-	-	-	No
25	1991	43	1	ARNG	Warrant	Fail	Fail	Pass	Pass	-	Yes
26	1991	45	3	ARNG	Warrant	Fail	Fail	Pass	Pass	Protanopia	Yes
27	1991	49	2	Civilian	Civilian	Fail	Fail	Pass	Pass	-	No
28	1992	29	2	Active duty	Commissioned	Fail	Fail	Pass	Pass	-	Yes
29	1992	33	2	Active duty	Warrant	Fail	Fail	Pass	Pass	-	Yes

Conclusions and summary

Chief, Visual Sciences Branch, U.S. Army Aeromedical Research Laboratory, requested a determination of the incidence of color vision deficiency among Army aviators. As we enter the next century, the color vision requirements of Army aviator will increase with the introduction of multicolored displays.

Since aviator training applicants are disqualified routinely from training due to color vision deficiency, there should be no aviators with color vision deficiency. However, this paper details incidents of exception to policy for known color vision deficiency, acquired color vision deficiency, and aviation medicine clinic screening program failures due to poor methods or deception by applicants and conspirators. The inflight evaluation of aviators discovered to have color vision deficiency is described.

The incidence of color vision deficiency was determined by review of records in the U.S. Army Aviation Epidemiology Data Register, to include archived aeromedical board documents, for the period of calendar years 1982 to 1992. Color vision deficiency among Army aviators is rare with an incidence of about 1 new case per 10,000 aviator-years per year. Two of 29 were granted exceptions to policy to complete flight training with color vision deficiency. The others (27 of 29) were granted administrative waivers to continue flying duties with their condition. Only half of the color vision deficient aviators underwent ophthalmology or optometry consultation. Only 17 percent (5 of 29) underwent an attempt to discover the axis of color vision deficiency. Only 59 percent (17 of 29) underwent inflight evaluations, despite the longstanding aeromedical policy requirement for all aviators with color vision deficiency to undergo inflight evaluations.

We recommend the U.S. Army Aeromedical Center continue quality assurance inspections of facilities conducting flying duty medical examinations and repeat color vision screening upon an applicant's arrival at Fort Rucker for flight training. Aviator training applicants with color vision deficiency should be disqualified from entrance into flight training. All Army aviators with color vision deficiency should have complete ocular examinations to rule out underlying disorders, determinations of the degree and axis of their color vision deficiency, and inflight testing of their operational color vision proficiency. Color vision standards should not be changed at this time.

We recommend the USAARL Crew Injury Branch determine if Army aviators with color vision deficiency are at increased risk for aviation mishap. The Visual Sciences Branch should develop computer-oriented color vision testing methods for the flight surgeon office, to include diagnostic modules in the case color vision deficiency is discovered. With the advent of increased color complexity in Army aviation cockpits, color vision performance studies are required to assess the risk for mishap and success of mission completion. These studies may lead to new recommendations for color vision screening standards for Army aviator training applicants.

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